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On the Estimation of Errors in Gridded Bathymetric Compilations

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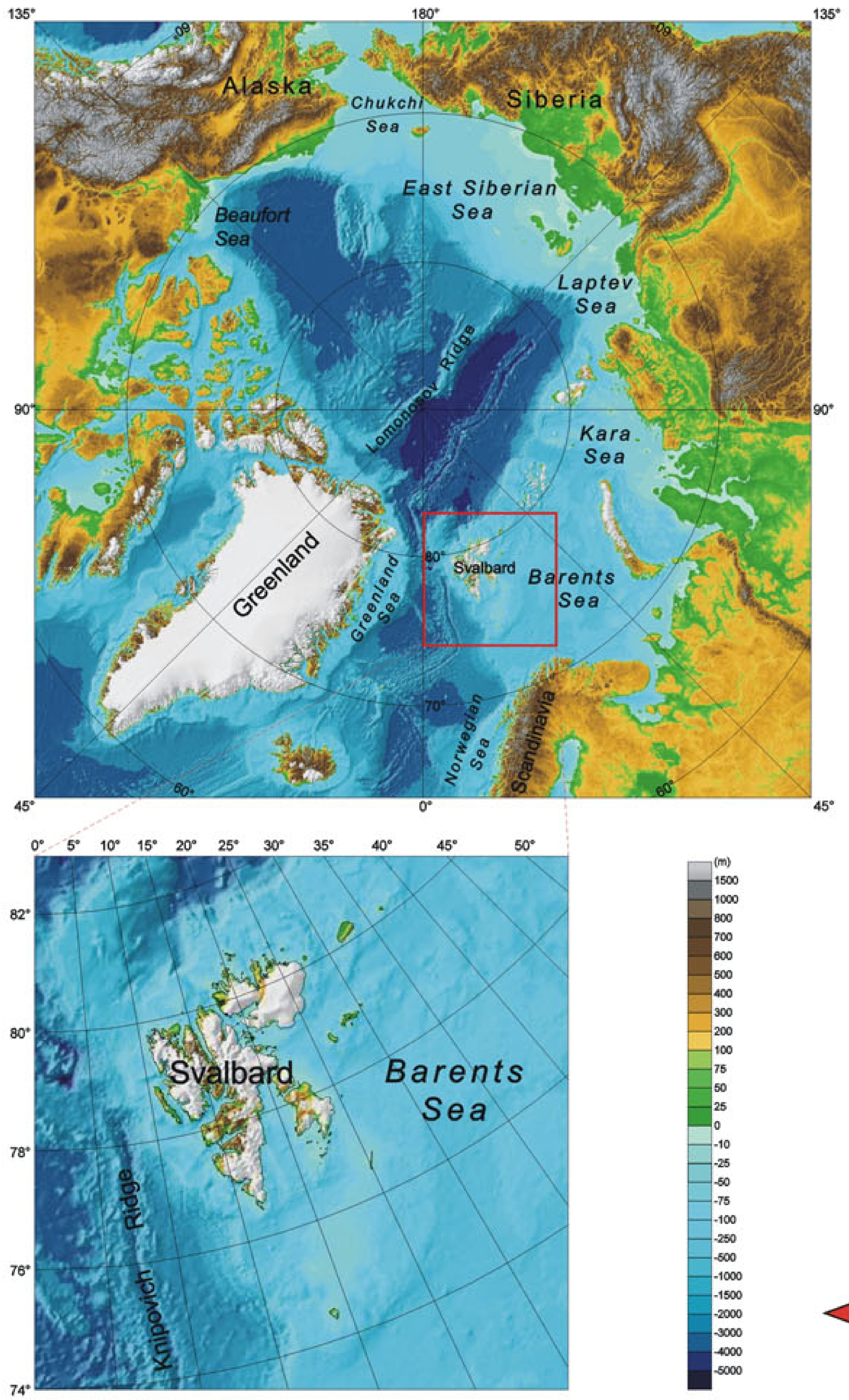

Background

Regional bathymetrical compilations of the world oceans that are based on a mixture of historic and contemporary data sets will remain the standard for a foreseeable future. An example is the International Bathymetric Chart of the Arctic Ocean (IBCAO) where all available bathymetric data north of 64° N have been compiled to a regularly spaced grid (Figure 1).

Such a compilation raises the problem of utilizing data sets with a heterogeneous cover and a wide range of accuracies. In combining these data to regularly spaced grids, which the majority of numerical procedures in earth sciences require, we are often forced to use a complex interpolation scheme. Consequently, we are faced with the difficult task of assessing the confidence that we can assign to the final grid product, a task that is not usually addressed in most bathymetric compilations. At the Center for Coastal and Ocean Mapping we have developed an approach where the confidence of such bathymetric grid model is evaluated via a direct-simulation Monte Carlo method.

Error modeling via direct-simulation Monte Carlo method

We have developed the error modeling approach by experimenting with a small subset of data from the IBCAO grid model (Figure 1). This grid is compiled from a mixture of data sources ranging from single beam soundings with available metadata to spot soundings with no available metadata, to digitized contours; the test data set shows examples of all of these types (Figure 2). From this database, we assign a priori error variances based on available meta-data, and when this is not available, based on a worst-case scenario in an essentially heuristic manner (Table 1). We then generate a number of synthetic data sets by randomly perturbing the base data using normally distributed random variates, scaled according to the predicted error model (Table 1). These data sets are then re-gridded using the same methodology as the original product, generating a set of plausible grid models of the regional bathymetry that we can use for standard deviation estimates. Finally, we repeat the entire random estimation process and analyze each run's standard deviation grids in order to examine sampling bias and variance in the predictions. The final products of the estimation are a collection of standard deviation grids (Figures 3 and 4), which we combine with the source data density in order to create a grid that contains information about the bathymetry model's reliability (Figure 5). In order to visualize the modeled uncertainty of the bathymetry we have used the Fledermaus software where standard deviation, expressed as percentage of depth, is color-coded on the 3D-bathymetry surface (Figure 6). This makes it possible for the geo-scientist interpreting the sea-floor morphology from the bathymetric grid model to take into account the uncertainty in the compilation and thus avoiding over-interoperations.

Figure 1. A color-coded shaded relief portraying bathymetry and topography of the Arctic region created from the IBCAO grid model with a nominal resolution at 2500m [Jakobsson et al., 2000]. The area subjected to our error modeling experiment is indicated by a bold rectangle.

Projection: Polar Stereographic with true scale at 75°N. Datum: WGS-84.

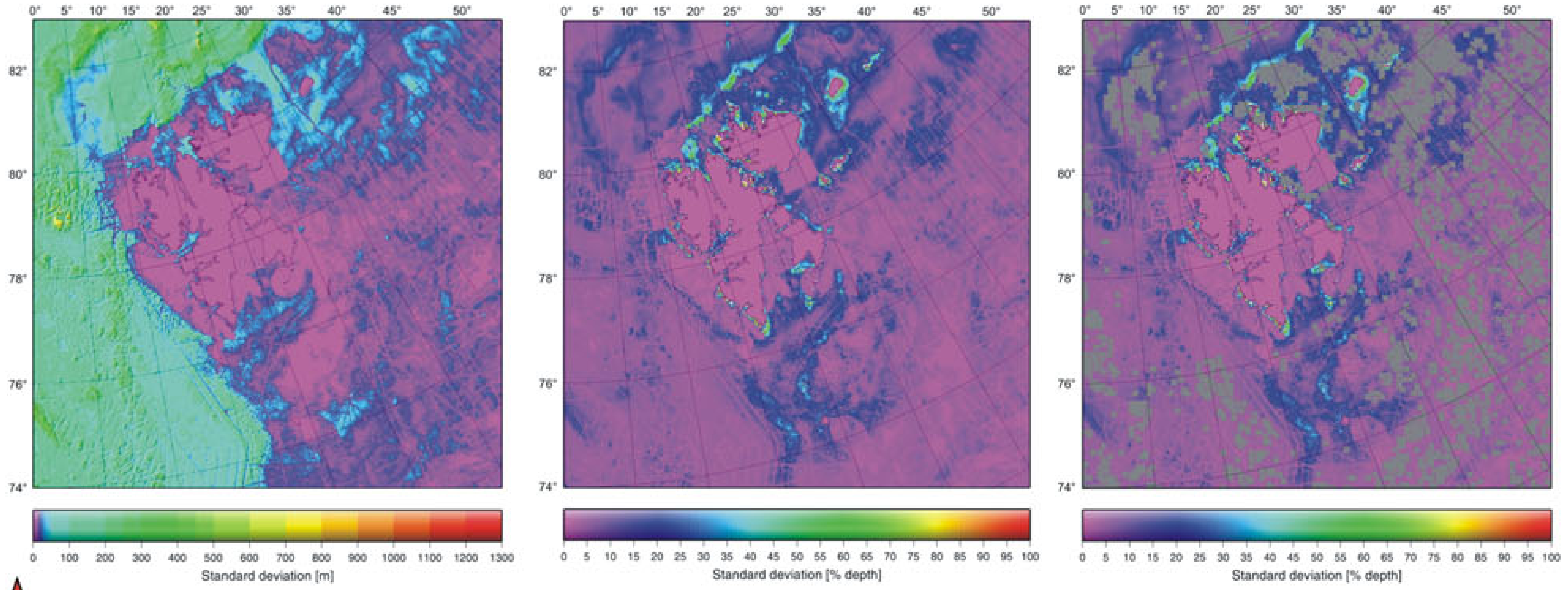

Figure 3-5. Standard deviation of gridded depth based on N=100 Monte Carlo simulation runs. In figure 5 grid cells containing no source data are colored in gray. Interpretation of the standard deviation in the grid where there is no data is essentially a function of the interpolation the GMT algorithm "surface" used in gridding, rather than actual errors caused by variability of data. We remove empty cells to avoid over-interpretation in sparse data.

Table 1. Classification of the source data shown in figure 2 and initial assignment of standard deviation of errors at 95% confidence interval.

Source data (error)	xy (m)	z (% depth)
Digitized contours		
Contours drawn during the IBCAO project (Yellow)	12000	5
Bathymetry of the Franz Josef Land Area [Matishov et al., 1995] (Magenta)	12000	5
Bathymetry of the Barents and Kara Seas [Cherkis et al., 1995] (Black)	12000	5
Bottom relief of the Arctic Ocean [Head Department of Navigation and Oceanography et al., 1999] (Orange)	12000	5
Soundings		
Swedish icebreaker Oden, 1991 and 1996 (Magenta)	100	5
Swedish icebreaker Ymer, 1980 (Red)	1852	5
US and British Royal Navies submarines, 1958-1988 (Lila)	10000	5
Data collected during SCICEX by USS Hawkbill, 1999 (Lila)	5000	5
Data from Norwegian sources (Black)	200	2
Soundings obtained from the US National Geophysical Data Center (NGDC) (Magenta)	1000	5

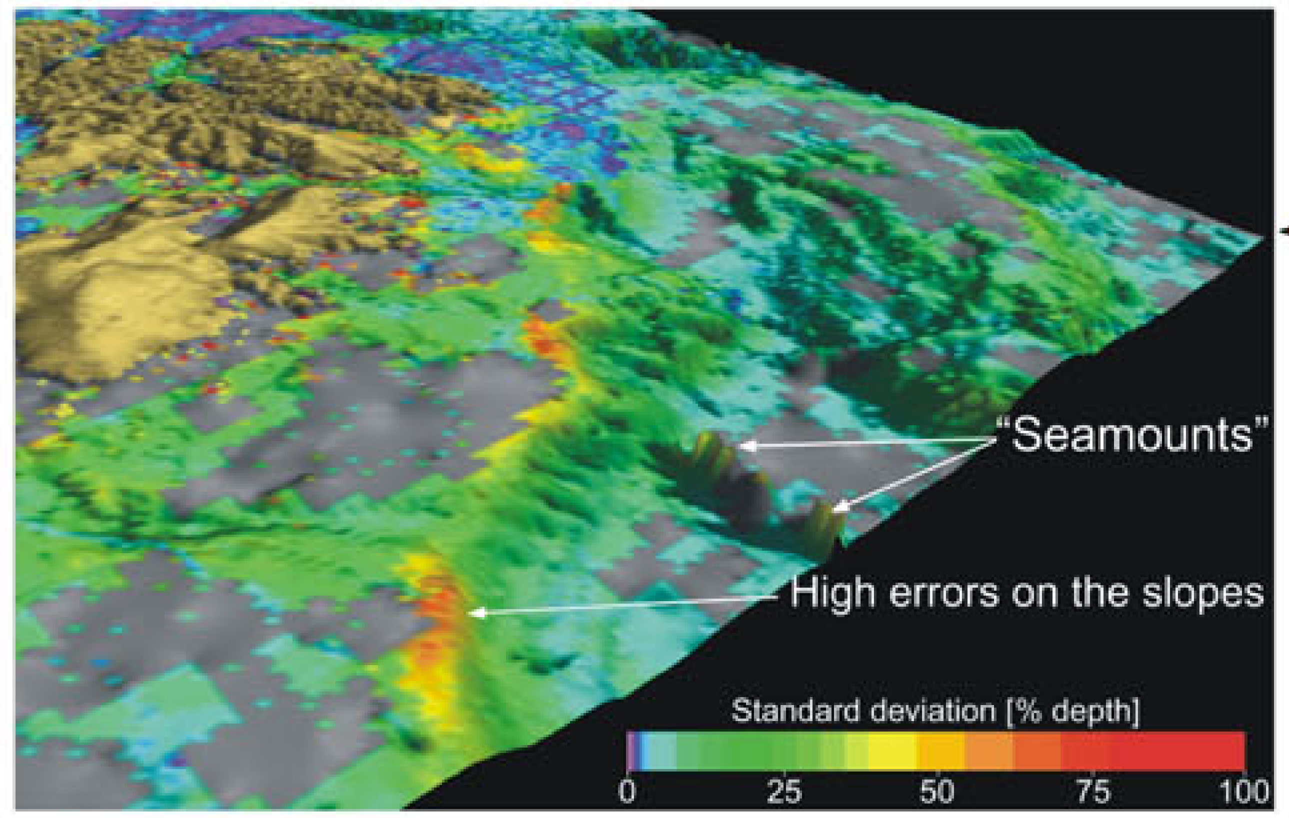

Figure 6. 3D-image, created using the software Fledermaus, showing the estimated standard deviation as a percentage of the depth draped on the IBCAO bathymetry. The error estimate shows clearly that significant error is associated with the indicated seamounts later revealed not to exist by a recent survey with R/V Polarstern.

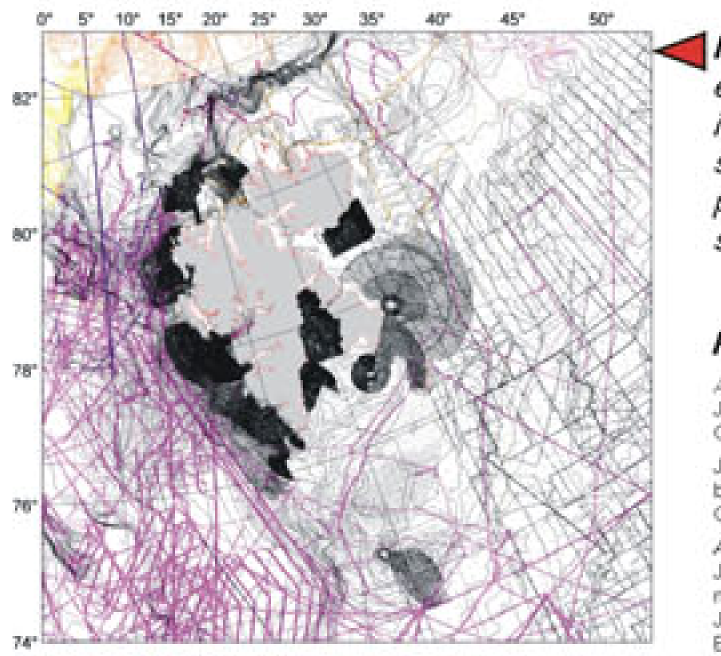

Figure 2. Data from the IBCAO construction database used for the error modeling. This includes all data that falls within the bounds indicated in figure 1 and covers almost all of the component data sets used in the entire IBCAO grid compilation. Projection parameters as figure 1. The key to the used color-coding of the source data is found in table 1.

Related Publications

Articles:

Jakobsson, M., Calder, B., Mayer, L., and Armstrong, A., submitted, On the Estimation of Errors in Gridded Bathymetric Compilations, submitted to Journal of Geophysical Research.

Jakobsson, M., Cherkis, N., Woodward, J., Coakley, B., and Macnab, R., 2000, A new grid of Arctic bathymetry: A significant resource for scientists and mapmakers, EOS Transactions, American Geophysical Union, v. 81, no. 9, p. 89, 93, 96.

Abstracts:

Jakobsson, M., Calder, B., Mayer, L., and Armstrong, A., in press, Error estimation of bathymetric grid models derived from historic and contemporary datasets, U.S. Hydro 2001 conference.

Jakobsson, M., Calder, B., Mayer, L., and Armstrong, A., in press, On the Estimation of Errors in Sparse Bathymetric Geophysical Data Sets, EOS Transactions, American Geophysical Union, v. 83.